THE VOWEL CHARACTER OF FORK TONES

By A. P. Weiss, Ohio State University

Introduction. This set of experiments was suggested by a series of observations made by Koehler (2) in 1910 while he was investigating the motions of the tympanic membrane during auditory function. In the analysis of the photographic records of the vibrations secured by this method it was found that when the vowel ō (fold)[2] was sung at about 500 vibrations. the form of the sound wave approached a pure sine curve. At about 200 vibrations the sound wave for ō (fold) became very complex, but the partial corresponding to the frequency 500 became prominent while the fundamental 200 almost entirely disappeared. This fact led Koehler to conclude that pure tones had an attribute or property which he designated as '*Vokalcharacter*' and that this attribute changed in quality at intervals of about an octave. Thus the '*Vokalcharacter*' of the tone 265 is ū (soon), that of 526 is ō (fold) and that of 1066 is ā (far).

In going over Koehler's results in a limited way it was not possible to differentiate these vowels unequivocally. From his familiarity with the work of Meyer (5) the writer wondered whether Koehler had not merely made a more intensive study of what Meyer had described as 'quality' and which

[2] The designation of vowels will be in the Revised Scientific (National Education Association) Alphabet Key. For those unfamiliar with this alphabet short English words in parentheses indicate the sound of the vowel. For reference to key see (1) in list of references.

was regarded as a continuous series ranging from the 'mellowness' of the lowest tones to the 'shrillness' of the highest tones with intermediate degrees of mellowness and shrillness for the intermediate vibration frequencies.

Experiments were planned bearing on this question. One investigation aimed to determine the vowel character as judged by untrained or partially trained subjects to get some idea of the acuity of discrimination in general. The orientation seemed desirable so as to plan a second experiment using refined apparatus and specially trained subjects with an intensive technique. The experiment with the untrained subjects was started and finished while work on the intensive apparatus was progressing. The latter was brought to a stop by the war which made it impossible to secure the quality of tuning forks necessary for the work. The writer regrets that the intensive results as originally planned cannot be included in this study; but since there is no prospect of getting the forks and the apparatus within a reasonable time, the qualitative results are presented separately for the benefit of those who already have the facilities and interest for the quantitative aspect.

Statement of the Problem. The experiments were designed to reveal the extent to which tuning fork tones resembled the vowels used in language. As a supplementary phase of the experiment there was also opportunity for considering the terminological aspect of the psychology of audition. The teaching of the attributes or simplest discriminations in hearing presents considerable difficulty to students, a difficulty which is perhaps only due to ambiguous or unfamiliar terminology. The divergences between musical and psychological practices in describing auditory phenomena are so great that some investigators think it hopeless to try to reconcile them. Among acousticians themselves the situation is not much better. A random list of the terms used by various investigators to describe the attributes of audition are: pitch, quality, tonality, vocality, tone-color, intensity, duration, volume, brightness, extent, clearness and local signature. Does this list of a dozen terms mean that twelve attributes may be discriminated? No investigator would maintain this. Does any particular term (say quality) mean the same for all investigators? Again the answer is negative. Indeed the pessimistically inclined would maintain that any one of the dozen terms may mean any one of the other eleven.

Surely if experts cannot agree, then to learn the opinion of the naïve subject cannot add appreciably to the confusion. Whether the ability to detect a resemblance to vowels in fork

tones is best described by the term quality, vocality, tone-color, brightness, volume, or any other term, will be determined in part by the ease with which untrained subjects can consistently discriminate vowels. If more consistent results are secured when the subject is asked to discriminate the vowel character than when he is asked to discriminate the brightness, quality or tone-color, supposing these all refer to the same fundamental attribute, then obviously vowel character or vocality is much the better term to use.

To test the value of a term, untrained subjects may often be used more effectively than trained subjects with special habits and prejudices toward a terminology developed under circumstances deviating very widely from the average class room conditions under which psychology is taught. Because of the lack of agreement on terminology no attempt will be made to determine whether the discriminations made by the subjects are attributive or cognitive in character. It is maintained only that an habitual or practical method of discrimination is demonstrated to the degree that there is consistency in the vowels that are assigned to the various fork tones.

Since performing these experiments Meyer (4) has suggested the term *vocality* as a substitute for his earlier term *quality* and as a shortened form of *vowel character*. It is in this sense that we shall use the term vocality in this article. Titchener (8) seems disposed to adopt the term vocality in the sense in which Meyer suggests, but Titchener has retained the term *volume* which is regarded as an attribute independent of the vocality. Rich (10) regards *pitch* and *volume* as independent attributes, but does not indicate the relationship between vocality and volume.

Simply stated our problem is to determine how consistently relatively untrained subjects can discriminate vocality in tuning fork tones and what utility the term vocality has in describing a fundamental fact in audition.

I. Experiment with Elementary Students

Class Experiment

A class experiment was given the last week in November, 1913 at Ohio State University to 150 students mostly freshmen and sophomores taking the course in elementary psychology.

Experimental Method. Ten Koenig tuning forks mounted on resonance boxes were placed at the front of the lecture room. The vibration rates of these forks were 128, 256, 320,

384, 512, 640, 768, 896, 1024, 1152 double vibrations. The subjects were instructed as follows.

> Each fork will be sounded twice. The first time it is bowed merely listen, eyes closed, and form a provisional judgment as to which vowel in the English language the tone most nearly resembles. The second time the fork is sounded make a final judgment and record a short English word which contains the vowel sound. The list of vowels and words on the board are to be regarded as merely illustrative. They do not include all the vowel sounds in the language nor all that may be used in reporting the vowel character of the fork tones.

The following is the list of vowels and words that was placed on the board:

e as in feel, *a* as in sale *o* as in tone *u* as in moon,
a as in far, *oi* as in boy, *yu* as in cure.

The tones lasted about three seconds. The recording was done on a narrow strip of paper, beginning at the bottom. As soon as the word was written it was folded out of sight. The next word was placed on top of the folded portion and it in turn was folded down. In this way there was no copying or referring back to previous judgments. In the presentation high and low forks alternated indiscriminately.

The term *series* as used in these experiments means a single presentation of each of the ten forks. A *discrimination* or *judgment* means that a fork tone has been sounded one or more times and that the subject has reacted to the tone by reporting, either orally or in writing, that vowel which in his opinion most nearly resembled the fork tone.

While performing the experiment it was noticed that the reactions were delayed and hesitating. Judging from the facial expressions the discriminations were difficult to make during the earlier part of the experiment but toward the end the reactions were more prompt.

After one week the experiment was repeated. This repetition is designated Series B; the original presentation as Series A. The second series was not expected by the students. The repetition was made to determine whether a second series would reveal greater uniformity and thus indicate some practice effect. The method was the same as for Series A. The results of both series are recorded in Table I. To enable direct comparisons with the subsequent experiments in which the number of subjects and the number of series are different, all results have been converted into percentages.

TABLE I

CLASS EXPERIMENT. TWO SERIES

First Series = A. Second Series = B.

One hundred and fifty elementary students. The values in the table represent percentages. Thus the first value 48 means that for the fork 128 in Series A, the vowel ū (soon) was reported in 48 per cent of the 150 judgments.

Forks / Series	128 A	128 B	256 A	256 B	320 A	320 B	384 A	384 B	512 A	512 B	640 A	640 B	768 A	768 B	896 A	896 B	1024 A	1024 B	1152 A	1152 B
ū (soon)	48	86	10	18	12	20	8	16	3	0	6	0	5	..	10	0	8	0	2	0
jū (cure)	6	0	10	0	10	0	4	0	6	0	11	0	8	..	8	0	6	0	5	0
ō (fold)	8	12	14	34	11	19	8	34	10	0	7	0	8	..	6	0	5	0	7	0
oi (boy)	4	0	7	0	9	0	10	0	14	0	10	0	14	..	8	0	5	0	8	0
å (far)	3	0	4	12	9	31	9	43	3	3	4	2	9	..	5	0	6	0	6	0
ai (fine)	1	0	3	0	9	0	15	0	24	29	22	25	18	..	14	33	16	42	18	31
ē (they)	4	0	22	34	9	27	14	7	10	35	7	20	10	..	14	34	9	12	12	13
ī (see)	15	0	15	0	14	0	15	0	14	33	14	50	15	..	17	33	21	46	18	53
failed	11	2	15	2	17	3	17	0	16	0	19	3	13	..	18	0	24	0	24	3

Last line 'failed' refers to the cases in which no judgment was given.
Average failures for Series A = 17 per cent; Series B = 2 per cent.
Average number of vowels assigned per fork: Series A = 8; Series B = 3.
In Series B, fork 768 was not available.

Table I. In Series A the failure to assign a vowel to the fork tones was nearly eight times as great as in Series B. The 17 per cent failures in Series A are not excessive however. If the same subjects had been asked to discriminate between ten degrees of saturation in colors, irregularly and successively presented, the failures probably would have been greater. That the failures decreased to 2 per cent in Series B indicates a rapid increase in skill with practice. In Series A the forks 128, 256, 512, 640 and 1024 have all of the eight vowels assigned to them, but some one of the vowels was used in more than one-fifth of the total number of judgments. In Series B the average number of vowels per fork was only three and every fork except 320 has more than one-third of the judgments given to some one vowel. This again implies a rapid increase in the uniformity of the reactions.

Nature of the Vowel Reaction. In Series A the percentage of ī (see) for all the forks was unusually large. The experimenter could not at first account for this fact. By bowing the forks gently the tones are so pure that no unpracticed subject would detect overtones and since the percentage was practically the same for all the forks it did not seem likely that the difficulty was in the source of the sounds.

It occurred to the experimenter that the subjects were not

only discriminating the particular vowel character of the tone but were also introducing an additional ĭ (see) vowel because they did not pronounce the vowel character of the fork tone orally. If for instance a fork whose vowel character resembles ō (fold) is sounded and an attempt is made to pronounce or sing the *o* silently, some consonant will be spontaneously supplied by the whispering and any vowel component of this consonant would be especially emphasized because of the instructions to differentiate the *vowel* character. Thus if the consonant *h* is supplied to the *o* to make *ho,* the *h* would not be differentiated as *h* because of this emphasis on the *vowel* character. If *h* is regarded as a semi-vowel, its silent pronunciation would resemble the oral pronunciation of *heee* and this in connection with the emphasized vowel *o* would give *heeeooo.* The *heee* would form a part of every fork tone and thus increase the frequency of the ĭ (see) reaction for all the forks.

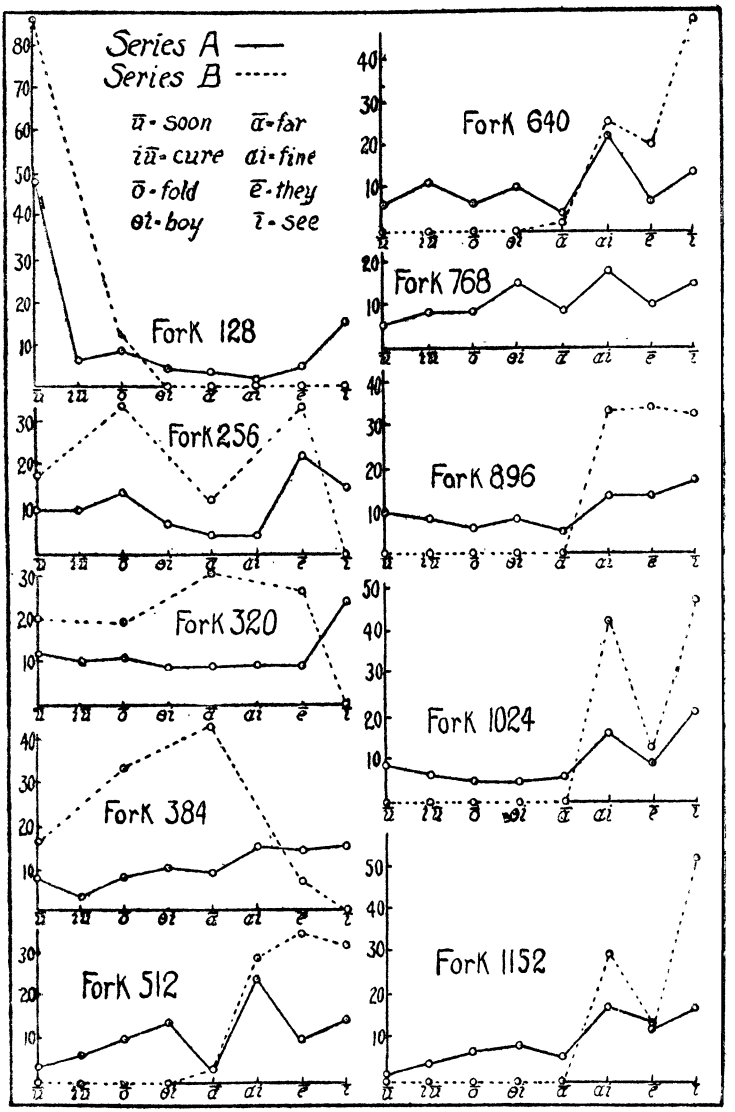
To restrict the analysis to the vowel character only, the experimenter, before Series B was given, called indirect attention to the consonants by stating that the vowel character of the fork tones may often be more easily analyzed if the subject will add consonants to the vowel sounds as is done in language. Thus we have pop, ish, peep, ho, ah, chirp, etc. It was hoped that by indirectly introducing the consonants their effect would be abstracted from the discrimination of the vowel character. The device seems to have been successful since the anomalous ĭ (see) distribution of Series A is absent in Series B. It was also pointed out that the sounds oi (boy) ai (fine), were not single vowels but diphthongs. This resulted in the elimination of oi (boy) and a restriction of ai (fine) to fewer forks.

Curves of Table I. The relation between Series A and B with respect to uniformity is best indicated by the curves. Each of the ten forks is plotted separately for both series. The vowels given on the base line are in the same order for all the forks.

If the vocality is independent of the vibration rates, the curves should approach the equation $y = k$ as a limit, approximately as is shown by the Series A curve for fork 320. Considering the Series A curves as a whole however, they would not be classed with the horizontal line type of curve. Series B is still further removed from the straight line type and the curves begin to give evidence of having definite maxima which in general augment the maxima of Series A. The maxima are toward the left for the lower forks; nearer the

CURVES I

ELEMENTARY STUDENTS. CLASS EXPERIMENT. VALUES TAKEN FROM TABLE I. EACH FORK PLOTTED SEPARATELY. VERTICALLY ORDINATE REPRESENTS PER CENT. VOWELS INDICATED ON BASE LINE



center for the intermediate forks; and toward the right for the higher forks.

The order of the vowels follows the series given by Koehler (3) : *m*, ū, ō, ā, ē, ī, the diphthongs not given by Koehler were interpolated.

Flexibility of the Vowel Series. In brief supplementary experiments not reported in this article it was found that when the subject is asked to determine the vowel character of a series, he usually assigns ū (soon) to the lower tones, and ī (see) to the higher no matter what the range of the series may be. There seems to be a tendency to condense or expand the vocality series to conform to the vibration limits of the tones used in the particular experiment.

If more intensive work will substantiate this it would mean that vocality is only partly dependent upon the absolute vibrations. Builders of musical instruments have adopted this partial dependence in the principle of 'voicing.' An organ builder may take two reeds both of 512 vibrations and voice one of them mellow and the other shrill, but he cannot voice the 512 reed so that it will be as mellow as a 128 or as shrill as one of 2048 vibrations. Similarity in voicing is restricted to a limit beyond which it is impossible to go. More space is devoted to this phenomenon under IX Discussion of Vocality.

II. Experiment with Laboratory Students

Individual Experiment [3]

To determine how the uniformity in vocality discrimination increases with subjects somewhat better trained in psychological observation, twenty-five series similar to those given the elementary class were given to six students taking the course in experimental psychology and two instructors in the department.

The ten forks were placed on a table in a room free from noise or other distractions and the subject sat about three feet away with his back to the forks. Before beginning, the nature of the experiment was explained and the subject instructed as follows:

The pure tone from the fork is to be analyzed as to its resemblance to the vowel sounds used in language. If a fork tone does not resemble any

[3] Mr. R. F. Bird, recently Fellow at the Carnegie Institute of Technology conducted the experiments with the laboratory students. His critical and painstaking tabulation of their data made it possible to add his results to those of Experiments I and III.

vowel with which you are familiar, the vowel or combination of vowels which most closely approximates the tone is to be given. The fork tones will be repeated as often as desired to enable you to make a judgment. The series of vowels on the card which has been given you is not to be regarded as complete, but only as indicating some of the sounds. Any other vowels may be used. If a vowel character seems to resemble two vowels, this is to be indicated by giving both vowels.

The following is the list of vowels and words that were placed on the card:

m as in hum, *a* as in ball *u* as in cue, *a* as in sale,
e as in feel, *o* as in tone, *i* as in high, *a* as in father,
i as in sit.

when the subject stated that the fork sounded equally like two vowels, as ū-ō for instance, this was counted as one-half for each of the vowels. Such double vowels occurred in less than one per cent of the total number of discriminations, and since the number of possible vowel combinations is large, each combination occurred so few times that no attempt was made to tabulate them separately. The most frequent combination ā-ē occurred only fourteen times.

Five series were given at a single sitting of about a half hour. The order of sounding the forks was varied for each series so the subject could not anticipate the next tone. The recording was done by the experimenter on previously prepared data sheets, the subject merely calling out the vowel and word.

When the first five series had been finished for the six subjects, the results were tabulated and it was found that all the vowel sounds that had been given could be grouped under the following vowels:

um as in hum	*a* as in sale	*a* as in ball
u as in cue	*i* as in sit	*e* as in met
o as in hoe	*i* as in high	*a* as in cat
a as in father	*e* as in feel	*u* as in full

The eight vowels in the first two columns were placed on a new card. The four vowels in the last column were omitted because they had been reported in less than two per cent of the cases. The revised card was then used for the rest of the experiment and the subject was requested to restrict his judgment to the vowels given on the card unless none of these were adequate either singly or in combination to express the vocality. In justification of this restriction it was found that the first eight vowels were in common use by all subjects including those who made use of the four vowels omitted.

During the early trials the subjects reported that the num-

ber of vowels at their disposal seemed too limited to describe all the fork effects. This difficulty was partly due to the unequal emphasis on the intensity and duration. Thus e (set) ē (they) are the same vowel differing only in length. A little practice however, soon enabled the subject to make due allowance for such variations but the more critical observers maintained to the last that when, for instance, two different forks were both reported to have the ō (fold) character this did not mean that the two *o*'s were the same. It implied only that the differences between the *o*'s could not be described in a consistent and satisfactory manner. Under IX Discussion of Vocality, further consideration is given to this limitation in the vowel analysis of fork tones.

TABLE II

EIGHT LABORATORY STUDENTS—TWENTY-FIVE SERIES FOR EACH SUBJECT—TOTAL OF 200 DISCRIMINATIONS FOR EACH FORK—THE VALUES IN THE TABLE REPRESENT PERCENTAGES—THUS THE FIRST VALUE 55 MEANS THAT FOR THE FORK 128 THE VOWEL UM (HUM) WAS REPORTED IN 55 PER CENT OF THE 200 DISCRIMINATIONS.

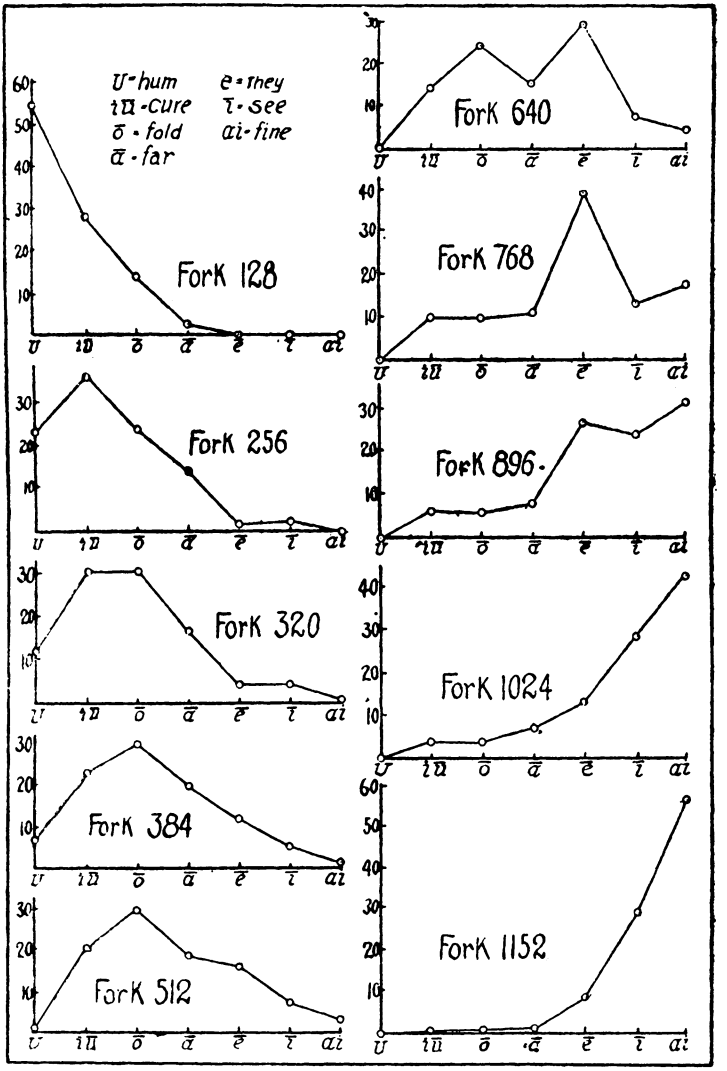
Forks	128	256	320	384	512	640	768	896	1024	1152
um (hum)	55	23	12	7	1	1	0	0	0	0
iū (cure)	28	36	31	23	21	15	10	5	4	1
ō (fold)	14	24	31	30	30	25	10	5	4	1
ā (far)	3	14	17	20	19	16	11	7	7	2
ē (they)	0	1	4	12	17	30	39	27	13	9
ī (see)	0	2	4	6	8	8	13	24	29	30
ai (fine)	0	0	1	2	4	5	17	32	43	57

Table II. There are no failures since each subject was free to have the tone repeated until he was able to assign some vowel. The percentages of any fork when read from top to bottom, or for any vowel when read from left to right, form a much more uniform series than for Experiment I with the elementary students. While the maxima are not as high as for Series B in Table I the geometrical relations between the series are more clearly shown. The maxima begin at one end for the lower forks (55 for 128) passing toward the center for the intermediate forks (30 for 512) and ending at the other extreme for the higher forks (57 for 1152).

The fork 640 seems to have two maxima, one at ō (fold) and the other at ē (they). This however does not interrupt

CURVES II

LABORATORY STUDENTS—INDIVIDUAL EXPERIMENT—VALUES TAKEN FROM TABLE II—EACH FORK PLOTTED SEPARATELY—VERTICAL ORDINATE REPRESENTS PER CENT—VOWELS INDICATED ON BASE LINE.



the progression except in a way that might be expected when the intermediate vowels are less clearly differentiated.

Curves for Table II. The plan of plotting the curves is the same as for Curves I. The graph for fork 128 has its maximum at the extreme left; for fork 1152 the maximum is at the extreme right; and for the intermediate forks it approaches either the left or right according as their vibration rates approach the upper or lower limits of the series.

On the whole the curves show a much more orderly progression than those for Experiment I. This would be expected from the more extended practice of the subjects and the change in the order of the vowel progression. In Experiment II the diphthong ai (fine) is placed after instead of before the vowel ī (see) as in Experiment I. While phonetically *ai* (fine) is a combination of ā and ī, yet since it ranks third in the order of frequency it seems probable that it is perceptually a unit for most subjects. However, the difficulty in placing this diphthong seems to indicate that there is a partial analysis.

III. Experiment with Teachers of Deaf Children

Class Experiment

To determine how consistently the vocality of fork tones could be discriminated by subjects trained in the analysis of vowel sounds, a class experiment similar to that given in Experiment I was performed before thirty teachers of the State School for the Deaf[4] at Columbus, Ohio. These teachers taught oral speech to children of all degrees of deafness. To detect and correct speech errors in those who cannot hear their own voices requires special ability in the analysis of vowel character and this ability should manifest itself even though the vowel character of the fork tones varies so considerably from the vowels of actual speech that the teachers are unable to use their special training to its limit.

The experimental method was practically the same as in Experiment I. Ten series were given instead of only one. The forks were not seen by the subjects. The tones were presented at random, each fork being sounded twice,—the first tone for orientation, the second for final discrimination. The subjects were instructed to listen to the tone and then record a word, the vowel of which resembled the fork tone. If no

[4] The writer takes this opportunity to thank Superintendent B. H. Jones for his interest and suggestions, and the teachers for their patience and conscientious effort during a trying hour.

vowel could be assigned nothing was to be recorded. Data sheets, ruled in squares with each square numbered were provided. At the top of the sheet were given the vowels:

um as in hum, *a* as in father, *o* as in tone, *a* as in cat
a as in sale, *i* as in fine, *u* as in cute.

The subjects were to regard this list as merely illustrative. Vowels not in the list were to be used whenever necessary.

TABLE III

THIRTY TEACHERS AT THE STATE SCHOOL FOR THE DEAF.—TEN SERIES—TOTAL OF 300 DISCRIMINATIONS FOR EACH FORK—THE VALUES OF THE TABLE REPRESENT PERCENTAGES—THUS THE FIRST VALUE 28 MEANS THAT FOR THE FORK 128 THE VOWEL UM (HUM) WAS REPORTED IN 28 PER CENT OF THE 300 TRIALS

Forks	128	256	320	384	512	640	768	896	1024	1152
uṁ (hum)	28	18	17	11	5	7	3	2	3	2
iu (cure)	16	15	18	11	9	21	14	13	10	7
au (now)	0	3	3	0	1	0	0	0	0	0
ō (fold)	10	10	11	8	10	16	5	4	2	0
o (not)	1	2	1	2	2	0	2	1	0	0
ä (far)	29	22	21	15	11	6	11	5	5	4
a (fat)	1	1	4	6	10	3	3	3	3	3
e (set)	0	1	1	5	7	6	4	5	6	4
ē (they)	2	4	0	10	4	8	5	7	5	6
i (sit)	2	2	1	4	5	8	20	20	17	13
ī (see)	1	2	6	3	7	7	11	20	30	32
ai (fine)	0	2	2	1	8	4	7	8	4	11
failed	10	18	15	24	21	14	15	12	15	18

Average failures = 16 per cent.

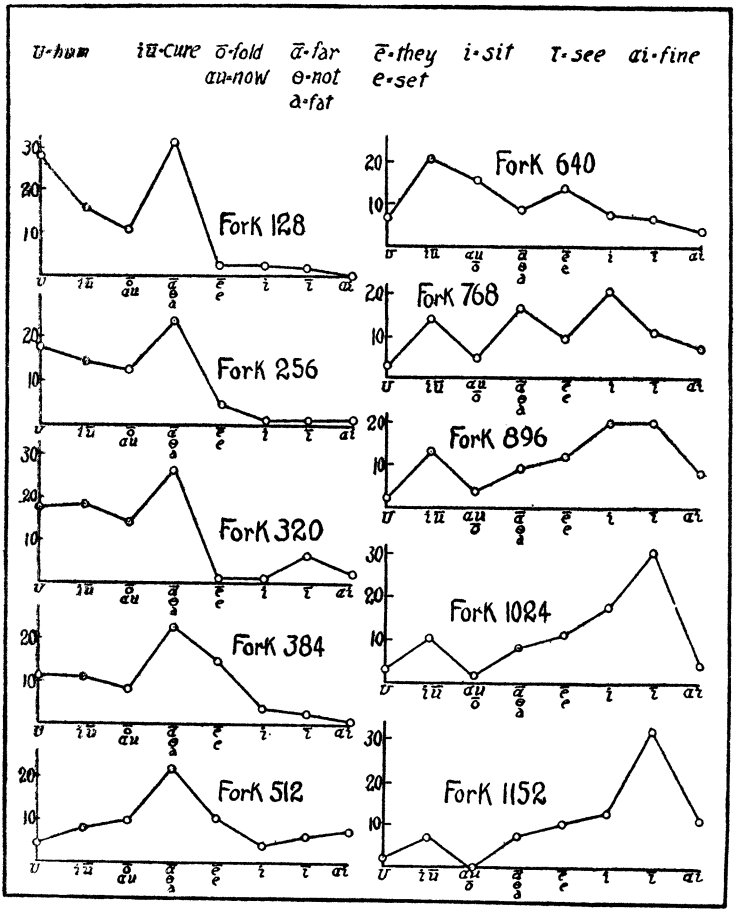
Table III. Perhaps the characteristic thing in the data of the teachers was the greater variety of vowels used, twelve as compared with eight for the Series A of the elementary students. The short vowels o (not), a (fat), e (set), i (sit), were used much more frequently than in the preceding experiments. The frequency of these short vowels is considerably less than of the long vowels, but there is clear evidence that the influence of the duration of the sound on the character of the vowel has been discriminated. This would be expected since the quantity of vowels is one of the important factors in teaching a non-hearing student to speak.

The relatively large percentage of failures was due partly to the instructions not to record the instances in which it was

impossible to decide upon the vowels, and partly to the novelty of being subjects in an experiment. The university students were more familiar with class demonstrations and laboratory work and the impressiveness of the occasion did not sit so

CURVES III

TEACHERS OF DEAF CHILDREN—CLASS EXPERIMENT—THIRTY SUBJECTS—VALUES TAKEN FROM TABLE III—EACH FORK PLOTTED SEPARATELY—VOWELS WHICH HAVE BEEN COMBINED ARE SHOWN UNDER EACH OTHER



heavily on their shoulders. Furthermore the attitude of 'trying to make a high score' was not so successfully eliminated with the teachers and this always has an inhibiting effect on the reactions of more mature individuals.

Curves III. To facilitate comparison with Experiments I and II the short vowels have been grouped with the corresponding long ones. The shapes of the curves correspond in general with the curves of Experiment I. The high frequency for ā (far) for the first five forks, seemed anomalous at first, but some of the teachers pointed out that this was the most ambiguous vowel of the series and where the discrimination was difficult this vowel served the purpose of a general utility vowel better than any of the others.

Considered as a whole the data may be regarded as complementary to the other experiments. It must be remembered that these teachers had not been trained for this particular type of discrimination. Their theories of vocalization, methods of teaching oral speech and past speech habits influenced their reactions to the auditory percept of the fork tones. Considering these factors it is rather remarkable that the results are as uniform as we find them. If these teachers had been asked to discriminate the series of fork tones into twelve degrees of quality, brightness or volume, with as little preliminary instruction as they received in discriminating the vowel character, the experiment probably would have failed.

IV. The Distribution of Vowels

To determine the differences between the vowel groups, the results of all three experiments were combined so as to include all the vowels given in Tables I, II, III. Such a combination will approach the average ability in vocality discrimination that would be expected from those subjects who are likely either as students or as teachers to exhibit a detailed interest in audition because of its practical or esthetic significance and to whose needs auditory terminology should be adapted if there are no scientific limitations. Thus if the term vocality is adopted it should not be difficult to explain to a musician what is meant by the ū-character of the lower end of the musical scale or the ī-character of the upper end.

No attempt is made to allow for differences in training, age, sex, experimental method and the variable number of series. Weighting separate experiments no matter how cleverly done, can never be a substitute for a uniform method in a single experimental plan. Yet since the aim is qualitative and the work

is regarded as preliminary to future intensive work, such a combination will give a conservative sketch that will help in developing a fruitful methodology.

TABLE IV

PERCENTAGE OF VOWELS ASSIGNED TO EACH FORK WHEN DISCRIMINATIONS IN TABLES I, II, III ARE COMBINED

Forks	128	256	320	384	512	640	768	896	1024	1152	Rel. Fr.
um (hum)	26	14	11	7	2	3	1	1	1	1	7
iu (cure)	44	25	25	17	12	16	14	10	8	5	17
au (now)	0	1	1	0	0	0	0	0	0	0	0
ō (fold)	12	21	19	21	15	16	8	4	3	2	12
oi (boy)	0	1	2	2	3	2	4	2	1	2	2
o (not)	0	0	0	1	0	0	1	0	0	0	0
ā (far)	13	17	21	23	13	8	11	5	5	4	12
a (fat)	0	0	2	3	4	1	2	2	1	1	2
ē (they)	2	14	9	12	16	18	19	20	10	10	13
e (set)	0	0	0	2	3	2	2	2	3	1	2
i (sit)	0	0	0	2	3	4	12	11	10	9	5
ai (fine)	0	2	3	4	14	12	12	18	24	27	12
ī (see)	3	5	7	6	15	18	14	25	34	38	16
Total...	750	726	732	698	705	721	584	730	729	709	

Total includes only the actual judgments. Percentages are derived from actual judgments made, failures not included.

TABLE IVa

DATA OF TABLE IV GROUPED INTO VOWEL CLASSES

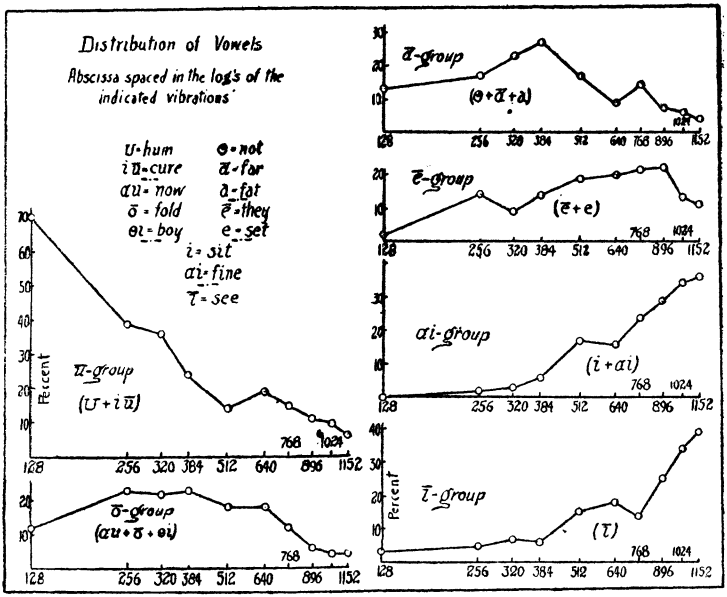
Forks	128	256	320	384	512	640	768	896	1024	1152	Rel. Fr.
ū-group	70	39	36	24	14	19	15	11	9	6	24
ō-group	12	23	22	23	18	18	12	6	4	4	14
ă-group	13	17	23	27	17	9	14	7	6	4	14
ē-group	2	14	9	14	19	20	21	22	13	11	15
ai-group	0	2	3	6	17	16	24	29	34	37	17
ī-group	3	5	7	6	15	18	14	25	34	38	16

Tables IV and IVa. All the vowels that were assigned in any of the experiments are given in Table IV. The last line marked 'Total' indicates the actual number of judgments only. If the failures had been included the total for each fork would have been 800. The low total of 584 for fork 768 is due to the fact that this fork was not available for Series B of

Experiment I. The last column (Rel. Fr.) gives the relative frequency of the vowels in per cent. Only six vowels have a frequency greater than ten per cent and these are selected as the more important classes. In Table IVa those vowels having a frequency of less than ten per cent are grouped together with those of the six important vowels to which they seem to belong. This gives the six *groups* of vowels shown in the first column. Each of these groups has a frequency that is large enough to determine the approximate vibration rate where the maximum frequency for a given vowel group lies.

CURVES IV

COMBINATION OF EXPERIMENTS I, II, III. SHOWING FREQUENCIES OF THE VOWEL GROUPS AT THE DIFFERENT VIBRATION RATES AS TAKEN FROM TABLE IVA.



Curves IV. The curve of the ū-group shows its maximum very decidedly at the fork 128. For the ō-group no decided maximum appears although its position is probably between 256 and 384 vibrations. The ā-group has a decided maximum at 384 and the drop on either side seems to justify the assumption that its highest frequency is more toward the higher forks than the ō-group curve. The ē-group curve is somewhat am-

biguous but in the reverse sense of the ō-group, its maximum seeming to lie between 512 and 896. The ai-group curve is similar to the ī-group; the maximum is at the highest fork used in the series, but shows evidence of having reached its highest frequency. For the ī-group the maximum is also with the highest fork but the slope of the curve at this work indicates that the point of highest frequency has not been reached.

A general consideration of the curves substantiates the statement made by Titchener (8) that the lower tones have a definite ū-character and the higher tones a definite ī-character.

V. The Consistency Between Vowels

The consistency in making the discriminations in these experiments approaches two limits:

1. When the consistency is least a subject will assign any vowel taken at random from his repertory of vowels every time he is asked to report the vowel character of any tone.

2. When the consistency is greatest a subject will assign the same vowel to the same fork every time it is presented.

The consistency may be measured by squaring the number of times a given vowel is assigned to a given fork. Thus if out of ten trials with fork 128 a subject reports 'u' *five* times, 'o' *two* times, and 'um' *three* times, the sum of the squares of the frequencies (5, 2, 3) is $25 + 4 + 9 = 38$. The number 38 measures the consistency.

If the subject had reported only a *single* vowel for all ten times, this would give a frequency of 10 for one vowel and the sum of the squares (since there is only one vowel) is $10^2 = 100$. The value 100 represents the upper limit or maximum degree of consistency.

If the subject assigns ten *different* vowels, each vowel can occur only once and the sum of the squares is $10 \times 1^2 = 10$. This represents the lower limit or minimum degree of consistency.

To make the measure of the consistency independent of the number of trials, the sum of the frequencies of the vowels squared, is divided by the square of the number of trials. By doing this the maximum consistency becomes 1.00 no matter how many trials are given, but the minimum will depend upon the number of trials.[5] Since the vowels available are relatively

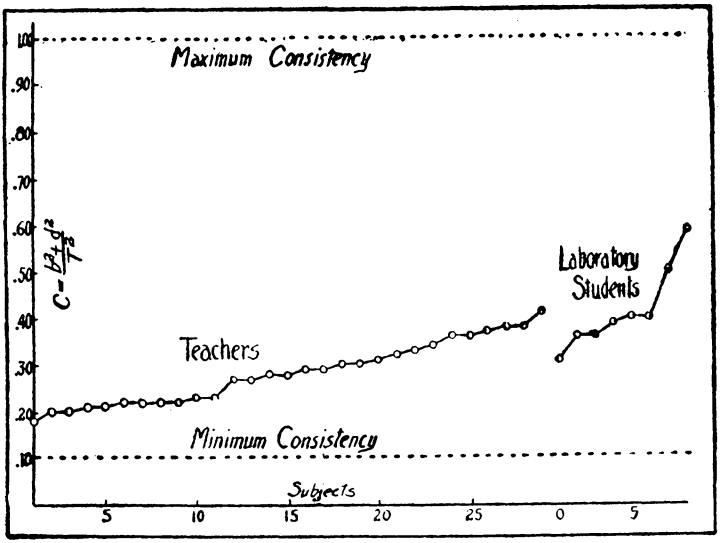
[5] The consistency (C) is algebraically expressed as follows: Let T represent the number of times a given fork is presented, and $b + d$ the number of times each vowel is assigned. Then $C = (b^2 + d^2) / T^2$.

few and both groups used the same vowels we can regard the minimum consistency as equal for both groups of subjects. For this we have selected $T = 10$ which gives the minimum consistency of .10.

Since there were only two series in Experiment I the consistency was not calculated.

CURVES V

INDIVIDUAL DIFFERENCES BETWEEN SUBJECTS AS MEASURED BY THE CONSISTENCY OF THE VOWEL DISCRIMINATIONS—SUBJECTS ARRANGED IN ORDER OF MERIT



Curves V. The dotted horizontal lines indicate the maximum and minimum limits of consistency. Each small circle on the intermediate curves represents one subject, and these have been arranged according to their degree of consistency. The vertical coordinate represents the average consistency for all the forks.

Considering the curve for the teachers, we find it relatively flat and that it does not indicate great individual variations. The median is at about 28 and this means that on the average

---

If the same vowel is assigned each time $(b^2 + d^2) = T^2$ and $C = T^2 / T^2 = 1.00$, the *maximum consistency.*

If a different vowel is assigned each time $(b + d) = T$ or $C = T / T^2$ the *minimum consistency.*

each subject assigned about three different vowels to each fork. For the laboratory students the median is at 40 indicating that on the average two different vowels were assigned to each fork. Out of a possible thirteen vowels actually used this represents a fair degree of reliability in making vocality judgments. If only the vowel *groups* indicated in Curves IV had been used in the measurement of the consistency it would have been more than twice as great and the curves would lie about half-way between the maximum and minimum limits.

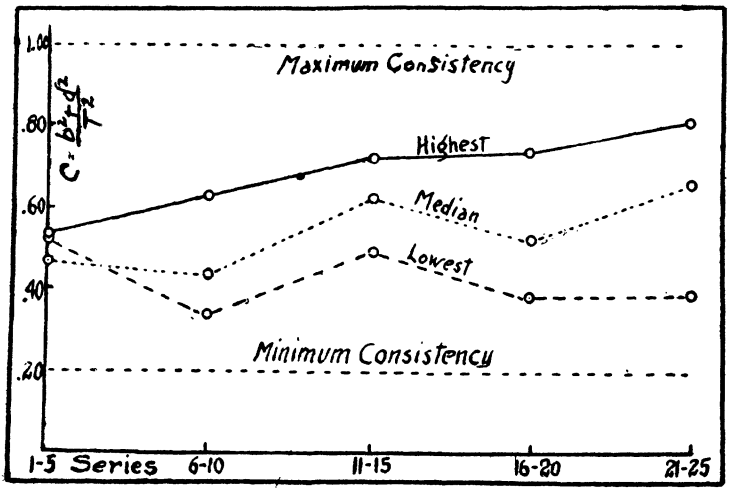
The individual differences between subjects conform to the usual results of those psychological experiments in which there is a gradual transition from one degree into another as for instance in auditory acuity. There is no evidence of a tendency toward a separation into two classes as into musical and non-musical subjects.

VI. Effect of Practice on the Consistency

In the Series B of Experiment I the consistency is much greater than for the Series A. The question arises what is the effect of practice upon the variability of the discriminations? In Curves VI the consistency for three subjects from

CURVES VI

PRACTICE EFFECT IN VOWEL DISCRIMINATION—THREE SUBJECTS FROM THE LABORATORY CLASS—THE CONSISTENCY IS CALCULATED AFTER EVERY FIVE SERIES



Experiment II was calculated for successive groups of five series each. The curve marked 'highest' represents the subject whose average consistency for the twenty-five series was greatest. The 'median' curve represents the subject who stood intermediate, and the 'lowest' curve represents the subject whose discriminations varied the most.

The curve for the 'highest' subject shows a gradual increase in the uniformity with each succeeding group of five series. The rise is not marked and signifies that a high degree of consistency had already been reached after the fifth series. For the 'median' subject there is a slight oscillation which probably implies that the consistency is no longer a function of training or practice after the first five series. This is more clearly shown by the 'lowest' subject whose curve shows even a slight drop between the fifth and twenty-fifth series.

The curves seem to indicate that the ability to discriminate vowels in tuning fork tones reaches a constant level after less than five series or after fifty discriminations. This of course does not mean that the maximum acuity has been attained. It merely indicates that the subject has isolated the vocality factor and that he is not confusing it with pitch, intensity, etc.

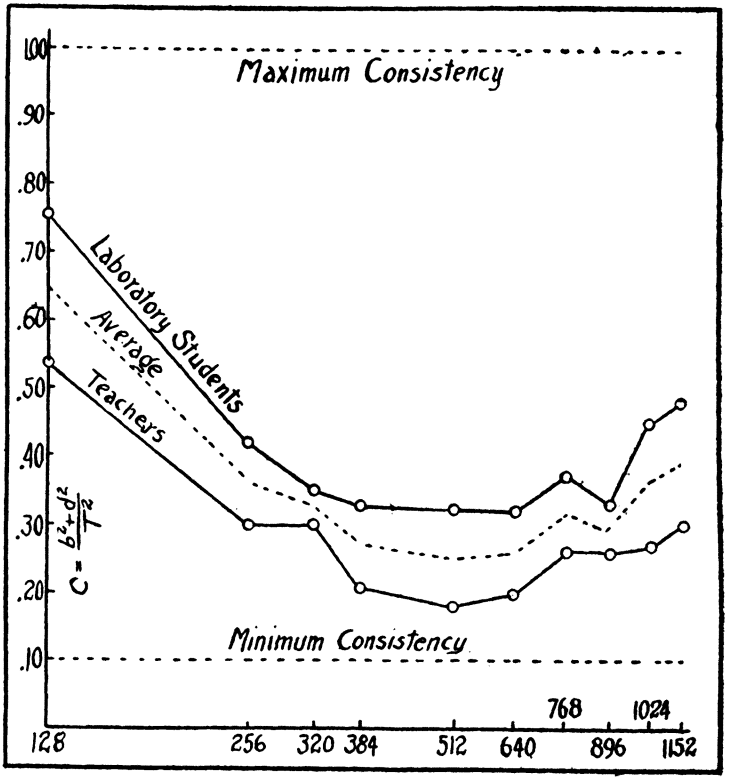
VII. The Consistency Between Vocality and Vibration Rates

The preceding topic indicated the individual differences between subjects. In Curves VII the individual differences of the forks, so to speak, are shown. The nearer a point on the curve approaches the dotted line indicating the minimum consistency the greater is the number of vowels assigned to it. To show the octave intervals as equal, the base line has been *spaced* in the logarithms of the vibration rates, although for easy reading the absolute vibration rates are given.

The curves clearly reveal that the forks in the middle region are more variable than the extremes. This is the opposite of pitch relationship or tonality which shows finer discriminations in the middle regions. The average consistency for the forks is indicated by the dotted curve. In consideration of the fact that these curves are based upon thirteen vowels, the degree of consistency is rather high. If only the vowel *groups* had been taken the curves would have been shifted upward to a median position between the limiting degrees of consistency and this would imply that on the average not more than two vowel groups would be reported for any one fork.

CURVES VII

RELATION BETWEEN VIBRATION RATE AND NUMBER OF VOWELS DISCRIMINATED—SUBJECTS FROM EXPERIMENTS II AND III



VIII. COMPARISON WITH THE WORK OF KOEHLER

In comparing the results of our experiments with those secured by Koehler it is necessary to allow for the different conditions under which the data was secured. Our comparison curve is a combination of three separate experiments. Koehler's curve is the result of theoretical deductions drawn from his own experiments and various other sources. Along the base of the Curves VIII the vibration rates of the forks are shown, spaced in logarithms.

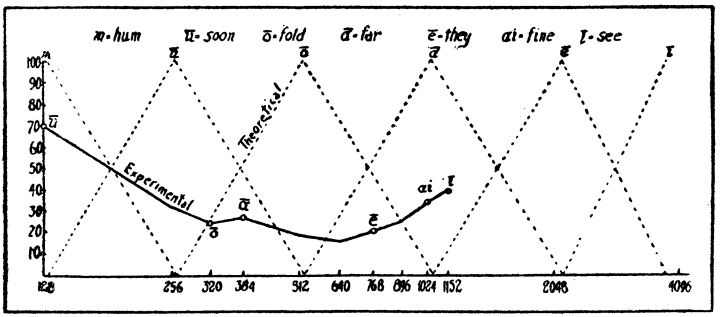
The dotted oblique lines represent Koehler's theoretical assumptions on the principle that each vowel has a maximum

frequency at some absolute vibration rate, with the frequency receding on either side until at the adjacent octaves its frequency is zero. These adjacent octaves however are the maxima for other vowels. Thus Koehler gives the vowel ū (soon) at 265; that is the vowel character of a pure tone of 265 vibrations is ū (soon) and under ideal conditions this vibration rate would be characterized as ū (soon) in 100 per cent of the judgments. As the vibration rate is increased, the subjects would characterize the tone as ū with a trace of ō. A further increase in the vibration rate would make the ō component stronger until a rate is reached at which the vocality resembles ū and ō. If at this vibration rate, which is indicated by the points at which the oblique lines cross, a number of subjects are required to report which of the two vowels ū or ō the tone most resembles, half of the subjects would report ū and half would report ō.

As the vibration rates are increased from this point the ō component becomes stronger until at 526 there would be 100 per cent ō judgments. In the same manner, as the vibration rate is decreased from 265 the vowel character approaches um (hum) until at 132 we have 100 per cent um judgments but none of ū. Whether or not the maxima should be connected with the respective minima by straight lines, Koehler leaves open for the present.

CURVES VIII

COMPARISON OF THE EXPERIMENTAL RESULTS WITH KOEHLER'S THEORETICAL ASSUMPTIONS—BASE LINE IS SPACED IN THE LOGARITHMS OF THE VIBRATION RATES



In order to combine the results of our experiments into a single curve upon which all the vowels are represented, rather than drawing a confusing nest of curves showing each of the

forks separately, we have retained only the maximal points of the separate vowels. For the intermediate forks we have taken from Table IVa the average of both the percentages involved. For instance, the maximum for the ū-group is at fork 128 and the per cent is 70; the similar fork for the ō-group is 320 and the per cent is 22; at the intermediate vibration 256 the per cent for the ū-group is 39 and for the ō-group 23. The average of 23 and 39 is 31 which is the value we have selected for our experimental curve at 256. For all the other forks, which were not themselves the maximum for a vowel group, the same method was adopted.

Whenever untrained subjects or general class experiments are used, there is usually a masking of those effects that would be revealed by more intensive methods. This masking may be so complete as to be a virtual obliteration. If however there are *relative* maxima and minima shown in the graphical representation of the qualitative results these should coincide more or less closely with the quantitative experiments just as the relative maxima and minima of the quantitative experiments should coincide with the theoretical limits of ideal conditions if the theory represents the facts.

From the experimental curve it will be seen immediately that there is only one decided maximum at ū (soon) and a less distinct one at ī (see). Our ū coincides with Koehler's *m*, but none of the other vowels correspond with Koehler's nor is there any evidence of symmetry in their distribution. By shifting our curve to the right one octave all of our vowels are brought within Koehler's octaves. But whether this rather strenuous stretching is justified by the difference in language habits (English as compared with German) will remain doubtful until this factor is itself made the basis of a special study.

IX. Discussion of Vocality

Relation between Vocality and Vowels. Perhaps the striking thing in making vocality discriminations is the fact that the fork tones do *not* sound like the vowels used in language but yet may be said to resemble them so closely that consistent judgments are soon made upon this basis.

Meyer regards the vocality as a continuous series limited on the one hand by the degree of mellowness of the lowest tones and on the other by the degree of shrillness of the highest tones; following this conception we may regard the vocality of the intermediate vibrations as varying combina-

tions of mellowness and shrillness. However to ask a subject to differentiate *degrees* of mellowness and shrillness directly, does not result in consistent reactions nearly so rapidly as when he is asked to discriminate the vowel character. Obviously this can only mean that the subject is not so familiar with the terms mellowness and shrillness as he is with the vowels of language.

Conventionalized Vocality Combinations. The vowels may be regarded as special names that have been given to those combinations of mellowness and shrillness that have been conventionalized into language elements. The vowel in actual speech is an auditory *complex* and its particular combination of mellowness and shrillness is only one of the components—that component however from which the vowel gets its name. There are of course many more combinations of mellowness and shrillness than manifest themselves in the vowels of any one language, but in speech an infinite number of vowels would be confusing and unnecessary. A dozen vowels meet the practical requirements of any one language. Convention and usage have determined which of the combinations shall be selected and the use of these has developed a degree of facility in their discrimination which gives them a predominance over all other possible combinations of mellowness and shrillness that are not used in language. The relative distinctness between vowels is thus merely an expression of the fact that we have selected and conventionalized those combinations which were most easily discriminated.

If the experimental conditions are such that the subject is asked to discriminate combinations of mellowness and shrillness that have not become conventionalized through their being a component of the language vowels, he describes them by the nearest of the conventionalized combinations (one of the vowels in his particular language) to which he already has learned to react. We might expect further that the vowels are rather closely related to absolute vibration rates because on the whole the range of the *average* human voice is rather restricted.

The Intervals in Vocality. The octave relationship which seems to exist between vowels may be regarded as a manifestation of the Weber-Fechner law. If a continuous physical series such as the frequencies of sound waves is to be divided into definite sensorial steps such as the vowels, the division will occur in equal logarithmic intervals rather than in equal absolute vibration intervals because the logarithmic intervals will give sensorial steps in which the dissimilarity between

adjacent steps is equal and greatest. That is, the equal logarithmic steps would become conventionalized rather than would the equal absolute vibration steps. This of course, would give a kind of an octave relationship for the given language. In other languages the apparent octave relationship may be based upon entirely different combinations of mellowness and shrillness. From the vowels and semi-vowels of all languages we might be able to construct a practically continuous series of all possible combinations of mellowness and shrillness.

Definition of Vocality. In the interest of uniformity in terminology the following definition or description of vocality is suggested:

Vocality is that attribute of auditory sensation which is described by the vowel and semi-vowel character of tones and noises. It may be regarded as a continuous series ranging from the degree of *mellowness* of the vibration rates at the lower limit of hearing to the degree of *shrillness* of the vibration rates at the upper limit. Various combinations of mellowness and shrillness manifest themselves as a resemblance to the vowel and semi-vowel sound: *m* (hum), ū (soon), ō (fold), ā (far), ē (they), ī (see), s, f, H, of which *m* is the mellowest and H [pronounced as the *ch* in *loch* (Scotch) or mi*ch* (German)] is the shrillest.

This definition or description is eclectic and is derived from suggestions of Stumpf, Meyer, Koehler and Titchener. If all investigators could agree to call this one property *vocality* and nothing else, and if they would exercise some restraint in the coining of new terms until they had assured themselves that they were describing a form of discrimination that had not been made by others, greater uniformity in terminology would result. If for instance, it is impossible to discriminate between two attributes of sensation then we have only one attribute and there is no advantage in giving this attribute two or more different names. If brightness (*Helligkeit*) cannot be discriminated from shrillness, then there is no difference between brightness and shrillness and one of the terms is sufficient. Which of the two terms will be adopted is of course immaterial. Priority in use is the simplest criterion.

X Summary and Conclusions

The problem was to determine,

A. How consistently relatively untrained subjects could discriminate the vocality or vowel character of tuning forks ranging from 128 to 1152 vibrations.

B. Whether the term vocality or vowel character is a suitable one to describe an attributive or cognitive fact of audition.

A. Consistency of Vocality Discrimination

From experiments with the elementary students (I)[6] we find even with only a single series that the ū (soon) character is predominant for the lower forks and the ī (see) character is predominant for the higher forks. The intermediate vowel classes, ō (fold), ā (far), ē (they), do not seem to have dominant positions at any particular vibration rate; but there is no question that they occur as a series without the possibility of interchanging their relative positions.

The results from the experiments with the laboratory students (II) show the same thing but in a more orderly manner. The discriminations of the teachers for the deaf (III) approach the results of the more specifically trained laboratory students (II) as well as might be expected when we consider the larger number of vowels used.

When the findings of all the experiments are combined (IV) and the vowels are reduced to six groups, each group has a relative frequency (Table IVa) which makes it probable that the group of vowels are associated in an orderly manner with corresponding vibration rates, but our experiments do not exhibit an octave or interval relationship (VIII).

There is no evidence of marked individual variation (V) between subjects in their general ability to discriminate vocality such as is supposed to exist between musical and non-musical subjects. A high degree of consistency is reached after relatively few vowel discriminations. For the elementary students (I) a marked improvement is shown after only one series. For the laboratory students (VII) the degree of consistency at the end of the fifth series (a total of fifty single discriminations) has practically reached the limit that is reached after 250 discriminations. The consistency of the vowel discriminations for the different forks (VI) is highest for the extremes and lowest for the intermediate forks.

B. The Term Vocality

From the rapidity with which the discriminations of vowel character become consistent (I, VI) it seems evident that when a subject is asked to discriminate the vowel character of a fork tone, the reaction is one that is already well estab-

[6] The roman numerals in parentheses refer to the headings from which the conclusions are derived.

lished by the ordinary (speech) habits of the individual. Practice (I, VII) improves the vocality discriminations so rapidly that no extended demonstrations are necessary to bring out the meaning of the term.

Improvement in the discrimination occurs spontaneously (III) and manifests itself by the addition to the vocality series of those vowels which are formed by lengthening or shortening the vowel sounds. Even when the discriminations become consistent the subjects (II) still report that while two tones of different vibration rates may be classed as resembling the same vowel there is still a difference between them which can be described as an admixture of another vowel sound but the degree of admixture cannot be reported with a high degree of consistency.

As a definition or description of the term vocality (IX) the following is suggested

Vocality is that attribute of auditory sensation which is described by the vowel and semi-vowel character of tones and noises. It may be regarded as a continuous series ranging from the degree of *mellowness* of the vibration rates at the lower limit of hearing to the degree of *shrillness* of the vibration rates at the upper limit. Various combinations of mellowness and shrillness manifest themslves as a resemblance to the vowel and semi-vowel sounds: *m* (hum), ū (soon), ō (fold), ā (far), ē (they), ī (see), s, f, H, of which *m* is the mellowest and H, pronounced as the *ch* in lo*ch* (Scotch) or mi*ch* (German) is the shrillest.

REFERENCES

1. FUNK & WAGNALL'S *Standard Dictionary*, 1913, page xxxviii.
2. KOEHLER, W. Akustische Untersuchungen I. *Zeitsch. f. Psychologie*, 1910, Vol. 54, p. 241.
3. KOEHLER, W. Akustische Untersuchungen II. *Zeitsch. f. Psychologie*. 1910, Vol. 58, p. 111.
4. KOEHLER, W. Akustische Untersuchungen III. *Zeitsch. f. Psychologie*. 1915, Vol. 72, p. 2.
5. MEYER MAX F. On the Attributes of Sensation. *Psychol, Rev.* 1899, Vol. 6, p. 506.
6. MEYER, MAX F. Zur Theorie der Geräuschempfindungen. *Zeitsch. f. Psychologie*. 1903, Vol. 11, p. 247.
7. MEYER, MAX F. *Vorschaege zur akustischen Terminologie. Zeitsch. f. Psychologie*. 1914, Vol. 68, p. 115.
8. RICH, G. J. Preliminary Study of Tonal Volume. *Jour. Exp. Psychol.* 1916, Vol. 1, p. 13.
9. STUMPF, C. Ueber Neuere Untersuchungen zur Tonlehre. *Bericht über den VI. Kongress für Exp. Psychol.* Leipzig 1914, p. 305-344.
10. TITCHENER, E. B. *Text-book of Psychology*. 1912, p. 94-95.
11. TITCHENER, E. B. *Beginners' Psychology*. 1916, p. 52.